AN EXPERIMENT IN THE APPLICATION OF CLIMATE FORECASTS:

NOAA- OGP Activities Related to the 1997- 98 El Niño Event

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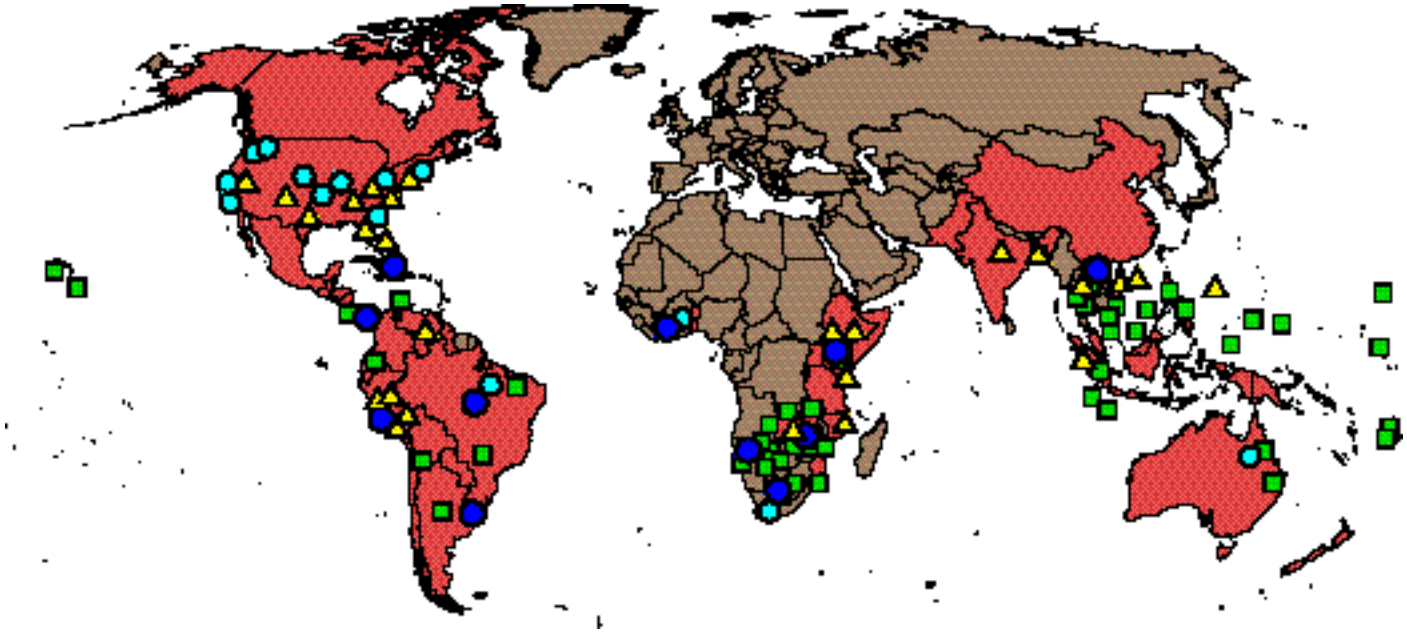

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LEGEND TO COVER GRAPHIC

Climate and Human Health (ENSO Experiment Research Activity)

Climate Outlook Forum

Economic And Human Dimensions Project

Pilot Application Project

(Countries reporting losses in OGP 1997-98 ENSO impacts study are marked in red. These are countries reporting losses during the 1997-98 El Nino, But not necessarily attributable to the warm event - See Appendix)

PREFACE

The United States National Oceanic and Atmospheric Administration-Office of Global Programs (NOAA-OGP) has participated in numerous long-term efforts to catalyze directed interaction among internationally-distributed groups of oceanic, atmospheric, and social scientists interested in research on climate variability and prediction, in cooperation with regional experts in climate-forecast applications and with potential sectoral users of climate information. NOAA-OGP's mission over the last decade has been, in part, to stimulate the first steps in learning how these groups'expertise can be integrated to construct common language and methodologies for better understanding the application of seasonal-to-interannual climate forecasts, and to support research activities toward this end. These scientific and user groups have coalesced over time based on a shared perception of a need for accurate, timely, and ultimately useable forecasts of climate variability related to the El Niño-Southern Oscillation (ENSO). During the 1997-98 El Niño, these groups worked together to provide experimental information in the absence of an established global infrastructure for coordinated climate forecasting and associated services.

Building on their experience, scientific and user groups for the first time mobilized collectively to help meet regional needs for advance information on severe weather-related impacts, such as droughts and floods, expected during the 1997-98 El Niño. Emerging seasonal-to-interannual climate-forecasting skills, technologies, and observation systems provided the tools to better predict the evolution of this event as well as the capability to provide probability-based forecasts of regional variations in rainfall and temperature several months in advance. More than a decade of program-based research on climate variability, forecast applications, and training in the Americas, Africa, Southeast Asia, and the South Pacific created the regional knowledge, expertise, working relationships, and demand for information that set the stage for this international response. Although largely research-oriented, these response activities made significant advances in mitigating damages from the 1997-98 El Niño. The indispensability of the evolving relationship between scientists who expanded the research envelope, the institutions that made regional application of climate information possible, and the users who were willing to risk making decisions on experimental forecasts cannot be overemphasized. Given that the event has recently ended, however, only time will allow a thorough evaluation of the usefulness of the international response.

Many of the activities summarized in this report have the goal of better understanding the translation of science into information useful in making real-world decisions. Although the event came midstream in the development of many of the regional climate-research and forecast-application activities in which NOAA-OGP and its partners were involved, the opportunity to bring climate forecasters and users together — often under crisis conditions — provided the additional momentum necessary to catalyze genuine utilization of forecasts. In responding to an actual crisis, the underlying intent of the international mobilization was to accelerate learning on how to more systematically and comprehensively apply climate forecasts, as well as to help countries mitigate impacts.

Well before the onset of the event, it was assumed that user needs would drive development of climate-forecast applications. When the event started, many scientists interested in climate variability had only just begun interacting with users who for the first time would stake real decisions on predictions of El Niño's evolution, and on a set of experimental, probabilistic forecasts generated and officially distributed in their regions. Users agreed to test this information because they tentatively accepted the premise that advance information on El Niño-related conditions would potentially improve their decision making.

The 1997-98 El Niño event provided strong motivation for both forecasters and forecast users to educate each other in the language of their respective disciplines and perspectives. The event stimulated a demand among decision makers for advance information on climate variability and an awareness

of where in the climate science community they could go for help. In turn, climate forecasters came to better understand the realities and needs of users, and some of the barriers to the use of climate forecasts. The 1997-98 El Niño thus provided an opportunity for learning that cut across disciplines, borders, and sectors by directing ongoing research and application activities in the service of an actual response. Ultimately, the impacts of the 1997-98 El Niño were at times unanticipated, but the cooperation improved the ability of forecasters to prepare for and recognize opportunities to assess El Niño's impacts in advance.

The efforts of scientific and user groups advanced the world's ability to manage impacts and to apply forecast information. But because efforts were dependent on limited research budgets and foci, a climate-forecasting system supported with appropriate technological and managerial infrastructure has yet to emerge. In short, these groups supplied and tested the best information currently available to assist affected countries, save lives, and protect vulnerable economies worldwide, but it will take more concerted and systematic efforts beyond research and reliance on select user communities to prepare for the consequences of future El Niño or La Niña events.

In the following pages, NOAA-OGP activities related to the most recent El Niño event, specifically those concerning the application of climate forecasts, are summarized and evaluated. Although the content of this report relies heavily on input from multiple contributors and reviewers, the document was written and edited primarily by David Lund and Josh Foster. Their dedicated effort and patience were essential to integrating the various parts into a coherent whole, and to sorting through the abundant editorial advice available to them.

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EXECUTIVE SUMMARY

This document describes activities of the National Oceanic and Atmospheric Administration's Office of Global Programs (NOAA-OGP) during the 1997-98 El Niño event. El Niño, an episodic warming of waters in the equatorial Pacific, causes shifts in global climate patterns and can result in severe flooding and droughts in areas such as Latin America, Africa, and Southeast Asia. Preliminary estimates indicate approximately 22,000 lives lost and $34 billion dollars in damages as a result of the latest El Niño (see Appendix). One of the most severe events this century, the 1997-98 El Niño was unique not only in terms of physical magnitude, but also in terms of human response. For the first time, affected countries around the world were aware of and could prepare for the climactic impacts associated with El Niño. This response was made possible by recent advances in climate-observing and -forecasting systems, creation and dissemination of forecast information by institutions such as the International Research Institute for Climate Prediction (IRI) and NOAA's Climate Prediction Center (NOAA-CPC), and individuals in climate-sensitive sectors willing to take the risk of acting on the forecast information by incorporating it into their decision-making processes. The supporting link between the forecasts and their practical application was a product of efforts by several national and international organizations, including, but not limited to, NOAA-OGP, the United States Agency for International Development Office of Foreign Disaster Assistance (USAID-OFDA), IRI, NOAA-CPC, the World Meteorological Organization (WMO), the Inter-American Institute for Global Change Research (IAI), the European Network for Research in Global Change (ENRICH), the United Kingdom Meteorological Office (UKMO), and the Asian Disaster Preparedness Center (ADPC).[1]

This retrospective serves to outline and review NOAA-OGP's contribution to the worldwide effort to practically apply climate forecast information during the 1997-98 El Niño event. The document is divided into three major sections, including the Pilot Program for the Application of Climate Forecasts, Regional Climate Outlook Fora, and Related Activities. The overall intent of these activities was to make forecast information broadly available to potential users, and to foster a learning process on how forecast information related to seasonal-to-interannual climate variability could be incorporated into practical decision making. This process provided a medium through which users could explore the capabilities and limitations of the climate forecasts currently available, and through which forecast producers could receive feedback from users on the utility of forecast products.

The NOAA-OGP Pilot Program on the Application of Climate Forecasts is a group of regionally-focused projects in Latin America, the Caribbean, the South Pacific, Southeast Asia, and Africa designed to provide mechanisms for transforming research results into information useful to representatives of climate sensitive sectors, and to distribute that information to key decision makers. Each pilot project involves four primary elements, including:

- Initial studies of the potential for climate forecast information to mitigate climate-related impacts in affected sectors (agriculture, human health, water resource management, disaster preparedness, etc.);
- Systematic production and distribution of experimental climate-forecast products to decision makers in selected sectors;
- Demonstration of regional forecasting capacity, and promotion of establishing a regional climate-forecasting network to interpret and apply new forecasting tools to decision making; and
- Continual revision and evaluation at each step of the process.

Pilot projects initiated by NOAA-OGP and its regional partners were designed to establish a framework for responding to forecast information in climate-sensitive sectors. For example, pilot projects

[1] Afull listing of NOAA-OGPpartners by activity-type is included in each section of this document.

in the Americas involved incorporation of ENSO forecast information into reservoir operation, hydroelectric power distribution, and agricultural production.[2] In the South Pacific, the Pacific ENSO Applications Center (PEAC) conducts research, produces information products, and performs outreach and educational activities in response to ENSO-related climate variability in United States-affiliated Pacific Islands. Pilot projects in the Southeast Asia region include basic studies of seasonal-to-interannual precipitation variability, training of Asian disaster managers on the use of climate information, linking of climate forecast and rice crop models, and forecasting the risk of dengue fever epidemics. In Africa, pilot activities have involved the incorporation of forecast information in water resource and agricultural management, analysis of climate-related risk in rural households, and studying the role of ENSO in disease transmission. Focused on a single topic as opposed to a particular region, the Climate and Human Health Program was initiated to study the human health impacts of the 1997-98 El Niño event. This program has supported research related to water-, vector-, and rodent-borne diseases in Latin America and the Caribbean, Southeast Asia, Africa, and the tropical Pacific. While NOAA-OGP has been involved in the initiation and support for these pilot projects, they are made possible through the dedicated efforts of institutions and universities in each region.

Pilot applications activities that had developed since the early 1990s provided a well-positioned set of efforts to serve user demands for information on expected 1997-98 El Niño impacts, and the background experience and contacts necessary to coordinate the creation and communication of climate forecast information prior to El Niño-related floods and droughts. At the core of this response were the Climate Outlook Fora, venues at which climatologists and meteorologists created regional consensus precipitation forecasts; and at which representatives from climate sensitive sectors discussed uses for forecast information. Working with domestic and international partners, NOAA-OGP organized and implemented a total of eleven Outlook Fora in Africa, Latin America, the Caribbean, and Southeast Asia during 1997-98:

Forecast Region	Forum Venue	Date
Southern Africa	Kadoma, Zimbabwe	Sept. 1997
Pacific South America	Lima, Peru	Oct. 1997
Southeastern South America	Montevideo, Uruguay	Dec. 1997
Southern Africa	Windhoek, Namibia	Dec. 1997
Northeastern South America	Fortaleza, Brazil	Jan. 1998
Greater Horn of Africa	Nairobi, Kenya	Feb. 1998
Southeastern Asia	Bangkok, Thailand	Feb. 1998
Western Africa	Abidjan, Ivory Coast	May 1998
Southern Africa	Pilanesberg, South Africa	May 1998
Mesoamerica	Panama City, Panama	May 1998
Caribbean	Kingston, Jamaica	May 1998

At each Outlook Forum, climate scientists fashioned integrated, 3-6 month, consensus-based, seasonal forecasts — or Climate Outlooks — for given regions. The Fora involved scientists and representatives of university and government forecasting organizations, National Meteorological and Hydrological Services, and international forecast centers. Many of the Outlook Fora were held in conjunction with pilot-applications design workshops, which allowed exploration of the uses of climate forecasts with potential users from sectors such as agriculture, fisheries, water resources, and disaster preparedness. In some instances, adjunct press briefings and conferences were convened to inform the general public of the issued experimental climate forecast and its potential applications. The principal goal of the Climate Outlook Fora was to develop regional capacity to produce and apply seasonal-forecast information through creating consensus seasonal forecasts and fostering a better understanding of user needs for climate information.

In addition to the Pilot Program on the Application of Climate Forecasts and the Climate Outlook Fora, NOAA-OGP supported and coordinated several activities during 1997-98, some of

[2] Pilot projects listed in the Executive Summary are not a comprehensive list of projects in any particular region. For a more complete listing of projects and participating institutions, see the Pilot Program for Application of Climate Forecasts section.

which were a direct response to the El Niño event, and others which had been ongoing programs for several years. Included in the latter group are the Economics and Human Dimensions of Climate Fluctuations Program, which focuses on social and economic impacts of climate change; and the Regional Assessments Program, the primary focus of which is the regional manifestations of global-scale climate variations and their effect on the dynamics of decision making in climate-sensitive sectors in the United States. Anewsletter edited and distributed by NOAA-OGP, the ENSO Signal, highlights advances in forecast applications, research techniques, and socio-economic issues related to the El Niño-Southern Oscillation. The ENSO Rapid Response Project, initiated in 1997, serves as a climate-information clearinghouse for monthly and other periodic updates of climate-forecast and observation products for officials in the United States and abroad. The California Pilot Project on the Use of Climate Information was established as a research project to study whether and how climate information affected decision making in various sectors in California during the 1997-98 El Niño. NOAA-OGP developed a web site to provide access to the latest observational and forecast information on the 1997-98 El Niño, and presented the information in a way that was understandable to the public, media, decision makers, and scientific users. Support was also provided for Applied Research Centers around the United States, many of which were involved in dissemination and application of climate information. These activities were multi-sectoral, involved both research support and operational activities, and spanned state, regional, national, and international levels, while contributing to the overall process of learning how to best utilize seasonal-to-interannual forecasts.

The introduction of climate forecasts on an international scale during the 1997-98 El Niño was an initial step in their practical application. Through activities in which NOAA-OGP and its partners were involved, it became clear that several issues need to be addressed to further facilitate the use of forecast information. Participants in the Pilot Applications Programs, Regional Outlook Fora, and related activities offered the following general recommendations:

- **Forecast accuracy and detail** — While many of the forecasts for El Niño-related precipitation deficits or excesses were quite reliable and promising in their utility, they were by no means perfect. Further application of seasonal-to-interannual forecasts will be aided by improvements in their accuracy and detail. This will be achieved through continued physical climate system research into the dynamics of ENSO and other ocean-atmosphere interactions outside of the equatorial Pacific. Regional detail will improve as computer models more accurately capture key climate system mechanisms and as computing power increases. In certain regions, forecasts based on historical data can be improved through compiling more complete and longer data sets of precipitation and temperature.
- **Validation** — A user of climate information must be confident that statistical or computer-based models will reliably forecast, within a reasonable envelope of error, future climate conditions. Thus, a common validation technique is necessary for prospective users to determine which forecasts are most reliable. Forecasters in various regions are currently using a multiplicity of verification methods for their individual forecasts which are often difficult to compare. The need to provide common verification methodologies across differing forecast systems has been recognized by the WMO, and an internationally-accepted standardized verification system (SVS) is currently being devised.
- **Training** — Training of forecast producers is required to ensure that common forecast generation methods are used across regions. This is particularly important if consensus forecasts similar to those generated at the Climate Outlook Fora are used in the future. Training for climate scientists and meteorologists should

involve exposure to: current modeling techniques, data requirements, model output interpretation, amalgamation of different data sources, and regional issues associated with ENSO and other types of variability in the climate system (e.g., the North Atlantic Oscillation). By making statistical climate forecasts of past conditions, and validating them with observational data, the quality of forecasts in the future will likely improve. Training and educational opportunities are also necessary for the user community, to foster a better understanding of the capabilities and limitations of current forecasting techniques.

- **Presentation** — Many of the forecast products generated during 1997-98 were presented as tercile probabilistic rainfall forecasts — that is, the probability that rainfall would fall into the wettest-third (above-normal), driest-third (below-normal), or middle-third (near-normal) of historically-observed values for a given area. Although "normal" in the tercile scheme is defined as the middle third of the historical record, to a potential forecast user, "normal" is a subjective term that could result in expectations for climate conditions different than those originally forecast. Expressing forecasts in alternate terms, of probability that rainfall will exceed a given amount (e.g., 75% likelihood of rainfall exceeding 20 cm over the next 3 months), or in terms of the probability of extreme rainfall events, would help address this issue.
- **Systematic creation and dissemination** — There is a need for a long-term strategy for the regular generation, dissemination, and application of forecast information in Latin America, the Caribbean, Africa, and Southeast Asia. NOAA-OGP and its partners are active in these regions to help develop regional forecast production and application capabilities. In Latin America and the Caribbean, for example, NOAA-OGP — in cooperation with USAID-OFDA, WMO, IRI, and several international and national organizations — is working to establish the Pan-American Climate Information System (PACIS). An agreement signed by the governments of Chile and the United States at the Summit of the Americas in Santiago (April, 1998) formally recognized the intent to establish PACIS. It is envisioned that this system will involve the monitoring, modeling, and prediction of climate and the interpretation and application of climate predictions for mitigation and response strategies. Creating systematic mechanisms and activities for climate forecast creation and dissemination will build on existing regional institutions and capacity, therefore enhancing the potential that the system will be maintained and further sustained with regional resources. Signs of forecast networks are emerging in Southern Africa, as indicated by the continuation of the SARCOF process into 1998-99, and in Latin America, the Caribbean, and Southeast Asia, where many consensus forecasting activities similar to the Outlook Fora are proceeding.
- **Pilot projects** — Continued implementation of pilot applications projects will: 1) help identify sectors particularly vulnerable to climate variability, 2) further understanding of the potential of user groups (for example, farmers, fishermen, government officials, state agencies, merchants, etc.) to respond to climate forecasts, and 3) result in creation and refinement of methods for tailoring forecast information to specific sectoral needs. Information will become more useful as forecasts are combined with models of river flow, hydroelectric power requirements, soil moisture, crop yields, and potential disaster scenarios. Research into correlations of climate patterns and disease outbreaks should be continued, and once established, examined for possible cause-and-effect relationships.

The global impacts of the 1997-98 El Niño event were severe and widespread, as evidenced by preliminary estimates of lives lost, monetary damage, and total number of persons affected. The

impact of climate phenomena on a given population is determined by two primary factors, including the exposure of the population, which is a function of the physical severity and location of a climate event in space and time; and the vulnerability of the population, which is a function of the economic resources, physical infrastructure, and institutional capability of the population to prepare for and mitigate the effects of climate phenomena. Since El Niño and La Niña events are part of a naturally-occurring cycle, there is little that can be done to change the exposure factor, barring mass migrations of people from high- to low-exposure regions. The second factor, however, is within our realm of influence. One way to reduce vulnerability of populations and resources to climate events is to aid preparation through the use of climate forecasts. The likely onset and severity of El Niño events can be predicted with promising accuracy, providing the lead-time necessary to mobilize governments, institutions, and individuals to prepare for ENSO-related climate variability. By making this information widely available during the 1997-98 El Niño event, and applying it to practical situations such as crop planting, water reservoir management, and natural disaster mitigation, we are beginning to learn how seasonal-to-interannual forecasts can be used as tools to reduce the socioeconomic vulnerability of populations around the world.

INTRODUCTION AND BACKGROUND

From the summer of 1997 through the spring of 1998, climate patterns representing substantial departures from normal affected many parts of the world. Regions such as the Pacific coast of South and North America, and the Greater Horn of Africa weathered severe flooding while portions of Brazil, Indonesia, and Papua New Guinea suffered from intense drought. On one end of the rainfall spectrum were flooded streets and crumbling hillsides in California, and on the other were the parched crops and scarce food supplies in Northeast Brazil. The primary cause of these climate patterns was El Niño, the episodic warming of waters in the equatorial Pacific that alters atmospheric circulation and climate patterns around the globe.[3] El Niño-related climate variability can affect agricultural productivity, water supplies, fisheries output, the integrity of transportation, telecommunications and civil infrastructure, and the spread of life-threatening and costly diseases such as malaria, dengue and cholera. Scientists consider the 1997-98 El Niño to be one of the most severe ENSO warm events of the 20th century, tentatively estimated to have caused the loss of approximately 22,000 lives, with at least $33 billion dollars in total costs from flooding, droughts, and associated impacts (see Appendix).

The purpose of this document is to summarize activities and evaluate responses implemented by NOAA-OGP during the 1997-98 El Niño, as a way of illustrating a number of possible research- and policy-related strategies undertaken in anticipation of climate events that will continue to occur. It is hoped that lessons learned can be applied to future scenarios involving climate variability and the use of climate-forecast information.

While the variability of climate is inevitable, the loss of human life and economic disruption associated with climatic fluctuations, such as result from El Niño or La Niña, can be mitigated by advanced warning and preparation of contingency plans. Unlike the 1982-83 El Niño, the onset and related impacts of the 1997-98 event were predicted well before they occurred, using the TOGA Array of sea-surface temperature-monitoring buoys in the equatorial Pacific, and predictive computer models with sophisticated mathematical simulations of coupled ocean-atmosphere interactions.[4] Computer generated predictions and forecast information products discussed in this document were created at NOAA's Climate Prediction Center (NOAA-CPC) and Climate Diagnostics Center (NOAA-CDC), the International Research Institute for Climate Prediction (IRI), and the Center for Ocean, Land, Atmosphere Studies (COLA). While each institution produced its own unique set of products and made them available to the global community, usually via the internet, CPC distributed these forecast data products primarily to reach decision makers in the United States; while IRI and OGP worked largely to analyze, interpret, and communicate information to those participating in Outlook Fora and other research activities overseas, or to provide information to U.S. government agencies operating internationally. In cases where OGP did provide information domestically, it was typically provided as part of research-oriented projects (see section on Related Activities).

Advances in the capability to forecast seasonal-to-interannual climate variability provided an unprecedented opportunity to prepare in advance for El Niño-related climate impacts, and to mitigate socioeconomic damages or in some cases to reap benefits. Building on regional pilot activities for climate forecast applications, NOAA-OGP worked to link international scientific and sectoral user groups around the world through planning, conduct-

[3] This ocean/atmosphere phenomenon is known collectively as El Niño-Southern Oscillation (ENSO). El Niño's counterpart is "La Niña," a periodic cooling of waters in the equatorial Pacific also accompanied by shifts in atmospheric pressure and in global climate patterns.

[4] For the purposes of this report: "predictions" generally refer to the projected state or condition of physical phenomenon in a particular location at some point in the future expressed in basic scientific form, e.g.,6-9 month advance estimates of sea-surface temperature; while "forecasts" generally refer to predictions that have undergone some form of interpretation, adding value so that they are intelligible and useful to decision makers, e.g.,Climate Outlook maps.

ing, or encouraging eleven "Climate Outlook Fora" and other related activities to stimulate the development and application of forecast information.[5]

The first section, covering NOAA-OGP's ongoing Pilot Program for the Application of Climate Forecasts, establishes a context for the Climate Outlook Fora, showing that responses to the 1997-98 El Niño were rooted in nearly a decade of research and organizational activities on climate forecast applications with partners around the world. The initial purposes of the Pilot Applications Program were to provide a prototype for regional climate-forecast research-and- applications networks; encourage integration between climate research and applications; study the feasibility of and perform trials on the concept of an "end-to-end" system that would produce and distribute forecasts to users during extreme climatic events; bring producers of climate forecast information together with users of that information; allow iterative learning to help refine all of these objectives; and promote an awareness about the International Research Institute for Climate Prediction (IRI) and its goals.[6]

The second section covers the methodology, regional conduct, preliminary evaluation, and recommendations of the various Climate Outlook Fora, many of which were planned before the 1997-98 El Niño occurred and served as a rapid means by which forecast information could be produced and distributed to users once the event was predicted. The third section summarizes research activities managed in concert with the 1997-98 El Niño not directly related to conduct of the Climate Outlook Fora, but relevant to NOAA-OGP's overall response to the event, including:

- ENSO Rapid Response Project;
- The "ENSO Signal" Newsletter;
- The California Pilot Project on the Use of Climate Information;
- The NOAA-OGP ENSO Web Site;
- Regional Assessments of Climate Variability, Social Vulnerability, and Public Policy Program;
- The Economics and Human Dimensions Program;
- The Pacific ENSO Applications Center (PEAC);
- Climate and Human Health activities under the ENSO Experiment; and
- Applied Research Centers

The Appendix outlines the impacts, both human and socioeconomic, associated with the latest El Niño event.

During the 1997-98 El Niño, NOAA-OGP encouraged the continuing interaction of scientific and user groups interested in climate forecasting and applications, urging these communities to capitalize on the opportunity to learn during an actual event. In parallel, it was anticipated that the severity of the event would increase the necessity for international, regional, and national entities to work in concert to mitigate impacts and to allocate additional resources toward this end. As a result, it was imagined that limited amounts of NOAA-OGP "seed" funding in support of design workshops, pilot projects, or Outlook Fora, pooled with resources from other international and regional partners, could be multiplied across regions, creating additional momentum for locally driven activities. NOAA-OGP viewed these research activities undertaken overseas as critical to improving understanding of climate-forecast applications in the United States. Finally, implementing these strategies was useful, in that they offer

[5] For the purposes of this report, "applications" generally refer to the use of climate predictions or forecasts in a decision-making context. "Users" generally refer to institutional or sectoral decision makers who can use climate forecasts to optimize their climate sensitive choices.

[6] For the purposes of this report, an "end-to-end" system is one that draws on scientific research to operationally produce, apply, and distribute seasonal-to-interannual climate forecasts to decision makers, who in turn feed back information to help enhance the research, and improve the production and distribution of the forecasts.

a glimpse of what it will take to provide the world with comprehensive climate-forecast services—built on managerial and technical infrastructure for observations, modelling, process research, assessments, and applications—as well as beginning experience on how to develop and deploy such a forecast system. Although climate forecasting is in its infancy, much progress has been made in the science of climate prediction, and there is yet tremendous unrealized potential for using forecasts to mitigate the effects of climate phenomena, particularly those related to El Niño-Southern Oscillation (ENSO). We believe that the activities summarized here are a first step in that direction.

Background[7]

The National Oceanic and Atmospheric Administration-Office of Global Programs'(NOAA-OGP) activities during 1997-98 were made possible, in part, by nearly fifteen years of ongoing programmatic research collaboration on climate science and forecast applications with partner institutions around the world. NOAA-OGPhas helped make seasonal-to-interannual climate forecasting possible through participating in various activities including:

- Conduct of the Tropical Oceans-Global Atmosphere (TOGA) Programme;
- Establishment of the TOGAAtmosphere-Ocean (TAO) array of sea-surface temperature monitoring buoys in the equatorial Pacific;
- Enhancing the ability to predict ENSO and related climate variability using coupled ocean/atmosphere computer models;
- Improving the capability to predict mid-latitude climate variability based on improved understanding of ENSO forcing;
- Launching of the International Research Institute for Climate Prediction (IRI);
- Developing regional forecast applications and the concept of an end-to-end system; and
- Stimulating demand for probabilistic climate forecasts.

NOAA-OGP participated in the Tropical Oceans-Global Atmosphere (TOGA) Programme from 1985-94 and is an active member of the World Climate Research Programme (WCRP).[8] In the wake of the unanticipated 1982-83 ENSO warm event and its severe worldwide socioeconomic impacts, the TOGA Programme was launched with the hope that the ability to observe and predict variations in ENSO would ultimately lead to better-informed decision making about how to manage impacts. In 1986, the first accurate experimental prediction of an ENSO warm event was made using a computer model. In the absence of a system for interpretation and distribution, however, this result remained largely within the scientific community. Although TOGA was breaking new ground in the understanding of climate variability on seasonal time scales, which ultimately led to the basis for seasonal-to-interannual climate forecasting, it was realized that it would take parallel development of new institutional mechanisms for predictions to systematically reach the broader policy and user communities.

In 1989, TOGA's Scientific Steering Group (SSG) recognized that the efficient transformation of scientific achievements into products useful for the global decision-making community required an independent means to advance climate research and foster related applications activities. During the early 1990's, the concept grew into a plan for a multilateral facility and an extended network of applications activities. An international task group in 1992 produced a proposal for an International Research Institute for Climate Prediction (IRI), which was repeatedly supported and developed by the TOGA/SSG, the WMO/IOC Inter-governmental TOGA Board, the WMO Executive Council, and the United Nations Conference on Environment and Development (UNCED)(Rio de Janiero, Brazil, 1992). After UNCED, the US launched an IRI Pilot Training Project, the objective of which was to expose small groups of climatologists, hydrologists, and agronomists from various regions, who were familiar with the impact of ENSO on agriculture and water resources, to state-of-the-art climate monitoring and short-term climate predictions.

Building on the recommendations from these groups, NOAA-OGP developed a Proposal to Launch a Seasonal-to-Interannual Climate Prediction Program (SCPP) and

[7] References:
- International Forum on Forecasting El Niño: Launching an International Research Institute, 6-8 November 1995, Washington, D.C., "Forum Proceedings," NOAA-Office of Global Programs, Washington, D.C., September 1996.
- National Research Council, "Learning to Predict Climate Variations Associated with El Niño and the Southern Oscillation: Accomplishments and Legacies of the TOGA Program," National Academy Press, Washington, D.C. 1996.

[8] The WCRP is an initiative of the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC), and the International Council of Scientific Unions (ICSU), which focuses on the extent to which the physical climate system can be predicted and on the impacts of human influence on climate.

presented it on behalf of the United States for the consideration of the international community at the International Forum on Forecasting El Niño: Launching an International Research Institute (November 1995, Washington, D.C.). NOAA-OGP is currently supporting a cooperative agreement with Columbia University/Lamont-Doherty Earth Observatory, and the University of California, San Diego/Scripps Institution of Oceanography to establish the institutional basis for the IRI, and to develop international partnerships for the sponsorship and management of the fully-multilateral IRI Core Facility, as called for during the 1995 Forum. The IRI is a first step in developing in practice the concept of an end-to-end system for climate research, forecasting, and applications.

NOAA-OGP has continued to be an active supporter of TOGA-based research through its Global-Ocean-Atmosphere-Land Systems (GOALS) Program, which contributes to the WCRP's Climate Variability and Predictability Program (CLIVAR), and through activities that assist the International Geosphere-Biosphere Programme (IGBP). In the area of forecast applications, NOAA-OGP augments the International Human Dimensions Programme (IHDP) and Global Change System for Analysis, Research, and Training (START), and collaborates with the WMO's Climate Information and Prediction Services (CLIPS) Project.